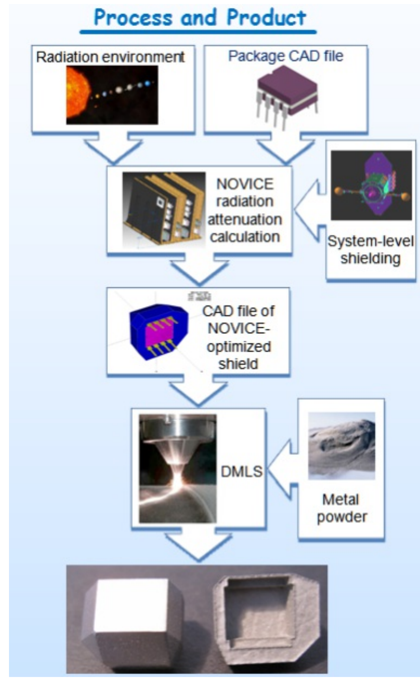
Completed Project (2012 - 2014)

Efficient Radiation Shielding Through Direct Metal Laser Sintering Project

Center Independent Research & Developments: GSFC IRAD Program

ABSTRACT

We have developed a method for efficient component-level radiation shielding that can be printed by direct metal laser sintering (DMLS) from files generated by the commercial Monte-Carlo particle transport code, NOVICE, modified for this purpose. The development of techniques for 3-D printing of otherwise difficult-to-fabricate shielding designs will reduce infusion risk of new electronics technology by providing a mass- and cost-efficient, effective mitigation of risks due to total ionizing dose. This component-level spot shielding technology readiness level is being raised through mechanical, thermal, and vibration testing and analysis of the complete shield-component-printed circuit board (PCB) system.



Flowchart of component shielding methodology (bottom portion of shield not shown). Final shield design accounts for collateral shielding available.

ANTICIPATED BENEFITS

To NASA funded missions:

- Reduce mass of electronics boxes for long-duration missions;
- Expand list of suitable electronic parts.

To NASA unfunded & planned missions:

- Reduce mass of electronics boxes in harsh radiation environment missions such as those flying in the radiation belts of Earth and Jupiter;
- Reduce mass of electronics boxes in long-duration missions;
- Enable use of electronic parts that would otherwise fail to meet mission total-ionizing dose requirements;
- Increase the mission lifetime of small-satellites which offer minimal collateral shielding.

To other government agencies:

- Enable use of electronic parts that would otherwise fail to meet mission total-ionizing dose requirements;
- Reduce mass of electronics boxes and/or increase mission lifetimes.

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To the commercial space industry:

- Enable use of electronic parts that would otherwise fail to meet mission total-ionizing dose requirements;
- Reduce mass of electronics boxes and/or increase mission lifetimes.
- Increase the mission lifetime of small-satellites which offer minimal collateral shielding.

To the nation:

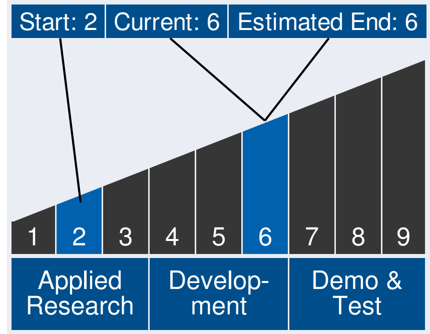
- Enable exploration of Jupiter and its moon, Europa, by reducing mass of electronics boxes in this harsh radiation environment mission.
- Increase the use of smaller, cheaper satellites to study Earth and the Sun by extending mission lifetime of small-satellites which offer minimal collateral shielding.

DETAILED DESCRIPTION

Functional and parametric degradation of microcircuits due to total ionizing dose (TID) often pose serious obstacles to deployment of critical state-of-the-art (SOTA) technologies in NASA missions. Shielding to the electronics box is used to mitigate TID degradation. Shielding materials can add significant amounts of mass to a system. One method for reducing mass is to apply “spot” shielding located only on the critical components that require it. Board area is often a constraint for spot shield design. 3-D printing technology offers promising breakthroughs in the design and deployment of radiation shielding optimized to the capability of the component, the mission radiation environment, and the shielding already provided by the component’s surroundings. Shields can be designed based upon the individualized package features to minimize area yet better protect from the omnidirectional radiation environment; such hand-and-glove fits would otherwise require complex machining.

Shield design is accomplished by the commercially-available NOVICE code. NOVICE radiation attenuation calculations use

Technology Maturity



Realized Benefits

1 New Technology Report

Management Team

Program Executive:
- Peter Hughes

Program Manager:
- Michael Johnson

Project Manager:
- Wesley Powell

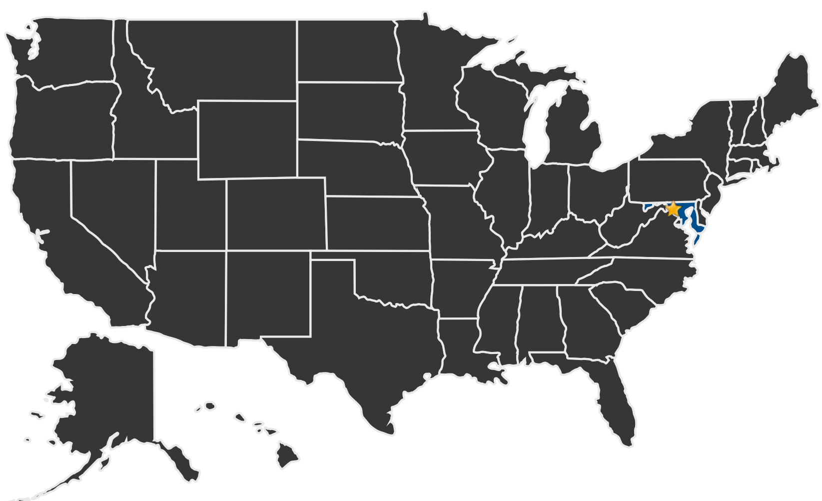
Principal Investigator:
- Jean-marie Lauenstein

Co-Investigators:
- Alvin Boutte
- Allison Evans
- Steven Kenyon
- Raymond Ladbury

the code’s ray-trace procedure in conjunction with 1-D attenuation data scaled for the different attenuation properties of the materials. A 3-D adjoint Monte-Carlo simulation verifies shielding effectiveness. NOVICE then generates the .STL CAD file for direct importation into a DMLS system.

We have demonstrated successful development, fabrication, and mass-savings of a DMLS additive-manufactured component-level prototype shield. The prototype shield was assembled to a PCB-mounted operational amplifier as a proof-of-concept and for Phase II functional evaluation necessary to bring this technology to TRL-6. Phase II efforts focus on environmental (vibration, thermal-vacuum) testing of the shield-component-PCB system. Additional goals include demonstration of reliable DMLS-printed shield design and fit across package types, and assessment of the manufacturing quality of the DMLS-printed shields across multiple manufacturers and materials.

U.S. WORK LOCATIONS AND KEY PARTNERS



U.S. States With Work

Lead Center:
Goddard Space Flight Center

Technology Areas

Primary Technology Area:
Materials, Structures, Mechanical Systems and Manufacturing (TA 12)
└─ Materials (TA 12.1)

Secondary Technology Area:
Modeling, Simulation, Information Technology and Processing (TA 11)

Supporting Centers:

- Goddard Space Flight Center

Contributing Partners:

- Experimental and Mathematical Physics Consultants

PROJECT LIBRARY

New Technology Reports

- NTR 1

News Stories

- Goddard's Storied Tradition Potentially Expanded Through 3D Manufacturing
    - (http://gsfctechnology.gsfc.nasa.gov/Launestein.html)

DETAILS FOR TECHNOLOGY 1

Technology Title

Efficient Radiation Shielding Through Direct Metal Laser Sintering

Technology Description

This technology is categorized as a hardware component or part for other applications

We have developed a method for efficient component-level radiation shielding that can be printed by direct metal laser sintering (DMLS) from files generated by the commercial Monte-Carlo particle transport code, NOVICE, modified for this purpose. Shield optimization accounts for the component packaging, printed circuit board (PCB) space, mission radiation environment, and collateral shielding provided by the spacecraft, electronics box, and other surrounding objects. Space-grade adhesives appropriate for the materials involved are used to mount the shield to the PCB.

Capabilities Provided

- Provide a mass- and cost-efficient method for mitigating risk due to total ionizing dose (TID) using direct metal laser sintering (DMLS) and the commercially-available Monte-Carlo particle transport code, NOVICE, to enable otherwise difficult to fabricate component-level shielding up to 4π sr.
- Reduce infusion risk of new electronics technologies through effective mitigation of TID exposure risks

Potential Applications

Listed below are potential applications for this technology:

- Harsh radiation environment missions such as the radiation belts of Jupiter (e.g. Europa Clipper)
- Long-term Earth-orbiting missions
- Small-satellite initiatives offering minimal collateral shielding

Performance Metrics

Metric	Unit	Quantity
Electronics box mass	kg	> 50%